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INTRODUCTION

Airports that are included in the Federal Aviation Administration's (FAA's) National Plan of Integrated Airports System (NPIAS) are referred to as "NPIAS" airports. NPIAS airports are eligible to receive both state and federal funds for planning and capital improvements; however, they are required to meet FAA regulations and standards for layout and construction. Airports that are not included in the NPIAS, but are included in the Washington State Aviation System Plan (WSASP), are referred to as Non-NPIAS airports. Non-NPIAS airports are only eligible to receive state grant funds for planning and capital improvements. This manual provides guidance for the development and construction of the following two categories of General Aviation Airports in the state of Washington:

STAGE 1, Small Community Airport: Intended to serve low activity locations, small population communities, and remote recreational areas. This type of airport accommodates about 75 percent of the airplanes under 12,500 pounds and can be the first step in development of a Stage 2, General Community Airport.

STAGE 2, General Community Airport: Designed for medium-sized population communities with a diversity of usage, such as personal flying, corporation flying, air freight, air taxis, crop dusting, powerline and pipeline control, and flying schools. This airport can accommodate about 95 percent of the propeller-driven airplanes under 12,500 pounds and should be structurally able to handle a large volume of landings by planes having a gross weight of more than 8,000 pounds. Aircraft service facilities are normally provided.

The purpose of this manual is not to replace federal construction standards but to offer guidelines that will allow a less expensive manner of improving the vast number of airports in our state that do not qualify for federal funding. Safety and economy have been of the utmost consideration in preparing these guidelines.

Guidance for the development and construction of larger airports, and those with commercial airline services, is provided by the Federal Aviation Administration.

Information or assistance may be requested from the Washington State Department of Transportation Aviation Division. If state funds are used in the construction of the proposed airport, a set of construction plans must be sent to:

Washington State Department of Transportation
Aviation Division
3704 172nd Street NE, Suite K2
P.O. Box 3367
Arlington, WA 98223-3367

I. REFERENCES

1. Federal Aviation Administration (FAA) Advisory Circulars (Use latest revision):

   150/5300-13 *Airport Design.*
   150/5320-5B *Airport Drainage.*
   150/5320-6D *Airport Pavement Design and Evaluation.*
   150/5325-4A *Runway Length Requirements for Airport Design.*
   150/5340-1H *Standards for Airport Markings.*
   150/5340-5B *Segmented Circle Airport Marker System.*
   150/5370-10A *Standards for Specifying Construction of Airports.*

2. FAA Order 1050.1D *Policies and Procedures for Considering Environmental Impacts.*

3. M22-01 Washington State Department of Transportation (WSDOT) *Design Manual*.

4. M23-03 WSDOT *Hydraulics Manual*.

5. M41-01 WSDOT *Construction Manual*.

6. M22-87 WSDOT *Utilities Manual*.

7. M26-10 WSDOT *Right of Way Manual*.

8. M41-10 WSDOT *Standard Specifications for Road and Bridge Construction*.

9. M31-16 WSDOT *Highway Runoff Manual.*

10. M21-01 WSDOT *Standard Plans.*

11. WSDOT *Pavement Guide for Design, Evaluation and Rehabilitation*.

12. American Association of State Highway and Transportation Officials, *AASHTO Guide for Design of Pavement Structures*, 1993.

13. NEPA (National Environmental Policy Act).

14. SEPA (State Environmental Policy Act).

15. *SEPA Guidelines*, Chapter 197-10 WAC.

16. Selected Climatic Maps of the United States (NOAA). These are 29 separate maps that show a great variety of information including temperature, precipitation, and wind.

17. Rainfall Frequency Atlas of the United States (NOAA), Technical Paper No. 40. This document is a convenient summary of rainfall data and is often used in the design of an airport drainage system.

18. Washington State Department of Ecology, *Stormwater Management Manual for Western Washington*, August 2001.

19. Washington State Department of Ecology, *Stormwater Management Manual for Eastern Washington Draft*, September 2002.

20. United States Department of Agriculture Soils Conservation Service.

Note:Weather data publications are available from the National Weather Records Center, Environmental Data Service, Federal Building, Asheville, North Carolina 28801

II. DESIGN DEVELOPMENT

Design development involves gathering together all the information necessary to prepare the contract document. Data accumulated during design development is used to determine the exact location of the airport, design criteria, and the materials and quantities required for construction.

A. CONTROL SURVEY

This survey establishes the control points used to determine the horizontal and vertical location of the airport. It also provides a basis for determining earthwork requirements, gradelines, and drainage patterns.

1. Airport Horizontal Control

Horizontal control establishes the geographic location of the airport. This references the airport to the location of important objects in the immediate area. Horizontal control is used to determine clearances and to assist in marking the airport property lines for purchase of needed land.

It is also necessary to establish the "Airport Reference Point" (ARP). This is a point that has an equal relationship to all existing and proposed landing and takeoff areas. On a single runway, the ARP is located in the centerline of the runway at the midpoint of the ultimate design length of the runway. Appendix 3 of the FAA Advisory Circular, AC No. 150/5300-13, *Airport Design; Change 7*, describes how to locate the ARP and is available from the FAA, 1601 Lind Avenue, Renton, Washington 98055 or on their website at http://www2.faa.gov/.

Once the location of the ARP is established, it should be converted into latitude and longitude, and should be computed to the nearest second.

2. Airport Vertical Control

Airport vertical control establishes the land elevations throughout the airport area. These are used to develop ground line profiles of all runways, taxiways, and buildings and are used to calculate earthwork quantities, pipe elevations, and all other earth measurements that are necessary.

B. PROFILE, CROSS SECTION, AND LINE OF SIGHT GRADES

Profile, cross section, and line of sight grades ensure that airport surfaces are steep enough to drain adequately while at the same time are flat enough to allow for safe operation of aircraft. Grades that are too flat result in standing water, which is a hazard to aircraft operations. Grades that are too steep result in aircraft veering off the runway or taxiway or sliding off in icy conditions. Apron grades that are too steep could result in aircraft rolling uncontrolled into other aircraft or in making it too difficult to maneuver aircraft either under power or when being pushed by hand.

Surface gradient standards are described in Appendix A.

C. DRAINAGE

Airport drainage ensures that the surfaces on the airport are adequately drained without standing water, which is a hazard to aircraft operations. Subdrains are also needed to keep the pavement section stable and free of groundwater. Water runoff and water quality have also become a very important design consideration. Stormwater runoff must be collected, stored, and released at an acceptable rate. This must be done without creating ponds that would attract birds, which could be a hazard to aircraft operations. Stormwater treatment must also be considered to keep pollutants from entering the groundwater and streams.

Airport Drainage/Stormwater Design methodology is discussed in Appendix B.

D. PAVEMENT DESIGN METHODOLOGY

Pavement design provides hard surfaces for aircraft operations. These pavements must be capable of handling the anticipated aircraft loads and aircraft operations. The pavements are also designed to withstand weather conditions and ground conditions, which could affect their performance.

The pavement design methodology is described in Appendix C.

E. AIRFIELD LIGHTING

Airfield lighting is designed to be a low-cost system that can be either a parallel or series circuit system. The system is designed to allow the use of "off-the-shelf" components for economy while at the same time incorporating those necessary elements that are required to make the system dependable and safe.

Airfield Lighting Parameters are outlined in Appendix D.

F. MARKINGS

Marking is recommended to provide guidance to pilots operating on the airport.

Marking standards are depicted in Appendix E.

G. TIE-DOWN ANCHOR

Tie-down anchors should be provided for protection of aircraft in windy conditions. A sample tie-down anchor is shown on Figure E-4 in Appendix E.

H. FENCING

Fencing is recommended along all property lines to protect the area from encroachment. In addition, fencing should be placed along buildings to maintain safety to the public and the pilot.

I. TERMINAL AND HANGARS

Building structures are usually listed as lump sum items. However, if the terminal is large and/or complex, it may be advantageous to list the electrical, plumbing, and other utility quantities as individual lump sum items.

J. ACCESS ROAD

Any roadway on the airport property is classified as the access road. Specifications for access roads are included in the specifications section of this document.

K. LANDSCAPING

Landscaping is provided around the airport runway and taxiway to reduce dust. Grass is normally used and is listed in the quantities by the acre. Other items such as bushes, flowers, etc. around the terminal should be shown as lump sum items.

L. COST ESTIMATE

Each item shown on the contract document should show an estimated cost. This price is used as a comparison against the actual bid price received in the contract award process. In those instances where the actual bid far exceeds the estimated cost, the itemized estimated costs will allow a review of the differences to determine possible modification.

See Table E-1 in Appendix E for a sample cost estimate.

III. STANDARD SPECIFICATIONS AND STANDARD PLANS

The *WSDOT Standard Specifications and Standard Plans for Road, Bridge and Municipal Construction* will be used for construction of Non-NPIAS airports. Listed below are some of the applicable sections of these documents used on airport contracts. They can be viewed in the WSDOT Standard Specifications.

WSDOT Standard Specifications (M41-10)

2-01 Clearing, Grubbing, and Roadside Cleanup
2-02 Removal of Structures and Obstructions
2-03 Roadway Excavation and Embankment
2-04 Haul
2-06 Subgrade Preparation
2-07 Watering
2-09 Structure Excavation
2-10 Ditch Excavation
2-11 Trimming and Cleanup
2-12 Construction Geotextile
3-01 Production from Quarry and Pit Sites
3-02 Stockpiling Aggregates
3-03 Site Reclamation
4-02 Gravel Base
4-09 Ballast and Crushed Surfacing
5-04 Asphalt Concrete Pavement
7-01 Drains
7-02 Culverts
7-04 Storm Sewers
7-05 Manholes, Inlets, Catch Basins, and Drywells
7-08 General Pipe Installation Requirements
8-01 Erosion Control and Water Pollution Control
9-02 Bituminous Materials
9-03 Aggregates
9-04 Joint and Crack Sealing Materials
9-05 Drainage Structures, Culverts, and Conduits
9-14 Erosion Control and Roadside Planting

WSDOT *Standard Plans* M21-01

Standard Plans for drainage structures and fencing are applicable for airport construction. (To view this information, see Standard Plans M21-01).

The following are FAA-based specifications, which have been adopted for use on Non-NPIAS airports.

P-401 Plant Mix Bituminous Pavement
P-620 Taxiway Painting
F-162 Fences and Gates
L-105 Airfield Lighting
L-108 Installation of Underground Cable for Airports
L-109 Installation of Airport Transformers and Power Supply Vaults
L-110 Installation of Airport Underground Electrical Ducts
L-111 Series Circuit Constant Current Regulator

IV. ENVIRONMENTAL CONSIDERATIONS PERMITS AND APPROVALS

Potential impact on the environment must be documented when considering airport development projects. Factors that can influence the development of land for general aviation use are:

air quality	soils
noise	schools
flooding	public services
ponding	utilities (water, telephone, electricity)
water quality	sensitive animal and vegetation habitats
sanitary systems	natural, historic, and cultural attractions
recreation	agricultural lands
scenic views	transportation systems
geology	parks

Airport development and construction projects that are funded with WSDOT Aviation Division Airport Aid Grant Program funds must meet all applicable environmental rules and regulations. If the development project is funded with any federal funds, the project must meet the guidelines established in the National Environmental Policy Act (NEPA). When only state funds are used, the project must comply with the guidelines established in the State Environmental Policy Act (SEPA).

Information on how to comply with NEPA environmental rules and regulations is contained in FAA Order 1050.1D, *Policies and Procedures for Considering Environmental Impacts*, and is available for download from the FAA's website by going to www.aee.faa.gov/e3/1050pt1d/. The FAA's Office of Environment and Energy may also be contacted at http://www.aee.faa.gov/, or the Council on Environmental Quality at http://ceq.eh.doe.gov/nepa/nepanet.htm. Mailing addresses are: FAA; Office of Environment and Energy; AEE-200; 800 Independence Avenue, SW; Washington D.C. 20591, and Council on Environmental Quality; 722 Jackson Place, N.W. Washington, D.C. 20503, (202) 395-5750.

For information on how to comply with SEPA environmental rules and regulations, contact the Department of Ecology office nearest you. The mailing address is: Environmental Coordination Section; Washington Department of Ecology; P.O. Box 47703; Olympia, WA 98504-7703 and the headquarters are located in Lacey, WA, (360) 407-6922. The SEPA Rules, SEPA Handbook, the RCW, and the publication *SEPA Guide for Project Applicants* may be found by going to www.ecy.wa.gov/programs/sea/sepa/

V. SITE SELECTION

A. SITE LOCATION

Many factors are involved in selecting an appropriate location for a general aviation airport. While it is not always possible to find a site that satisfies all criteria, consider each of the following factors and incorporate as many as possible.

1. Accessibility. The site should be readily accessible to users, preferably adjacent to a highway or to an acceptable railway terminal.

2. Costs of Land. (Comparative costs between sites.)

3. Future Expansion. Land in the vicinity of an airport increases in value once an airport is built. Consequently, future expansion of the airport should be considered when initially acquiring airport land.

   The financial burden of acquiring sufficient land for eventual airport expansion can be eased by leasing the surplus land to nonconflicting users, usually on a one- to five-year lease. For example, a future building area not immediately needed for airport development can be used for a variety of revenue-producing activities, such as agricultural operations. Limited agricultural use is also compatible with the runway protection zone approach area; however, no structures should be allowed in this area. Avoid the establishment of landfill facilities or other operations that would attract birds to the runway vicinity. Care must be taken to ensure that any lease agreement does not conflict with either present or future airport operations.

4. Zoning. Under Washington State's Growth Management Act, airports are considered Essential Public Facilities (EPFs) and cities and counties that have public use general aviation airports located within their jurisdictions are required to discourage the siting of incompatible land uses adjacent to their airports (RCW 36.70A. 510 and RCW 36.70.547). To accomplish this, local jurisdictions should include the airport in the Comprehensive Plan and local development regulations (zoning). In order to be fully protected under Washington State land use law, airports must be included in both the Comprehensive Plan and the development regulations.

   Zoning ordinances to allow flight operations must be completed at the earliest possible date. The Revised Code of Washington, Chapter 14, details zoning rights and regulations as they affect local agencies and should be reviewed very carefully prior to any action taken. It is imperative that areas adjacent to a proposed or existing airport be considered in the zoning study. This will ensure proper consideration of all zoning needs.

Whenever existing zoning ordinances must be revised, or new zoning ordinances must be enacted to allow airport traffic, the ordinances should reflect the ultimate design of the airport, even if that design is several years in the future. It is much more difficult to revise a zoning ordinance at a later date than it is to get full clearance at the start of the airport project.

5. Temperature/Elevation. Both temperature and elevation affect runway length, as illustrated in Figure 1. Figure 1 shows how to calculate minimum runway length based on the site elevation above sea level and the mean daily maximum temperature for the hottest month of the year. The mean daily maximum temperature for the hottest month of the year can be obtained from the National Oceanic and Atmospheric Administration's (NOAA) local National Weather Service Office or from the NOAA publication *Climatography of the United States No. 86*. (See Section I. References, for a list of other NOAA publications.)

6. Wind. The runway should be oriented in the direction of the prevailing wind. Where wind direction varies, crosswind runways should be considered. Information about temperature and wind may be obtained from NOAA, or from a National Weather Service Office. In some areas of the state, data on wind direction is not available and a wind rose will have to be developed by the prospective airport builder. Data collected for a period of even one year will be beneficial, especially when used in conjunction with local information. If needed, equipment used to obtain the appropriate air and wind data may be rented from the WSDOT Aviation Division.

7. Other. The following climatological data must also be considered:

   a. Annual rainfall.
   b. Average frost penetration.
   c. Snowfall.
   d. Prevalence of smoke or fog.
   e. Unusual weather conditions.

B. LAND REQUIREMENTS

1. Recommended Dimensions. Figure 2 is a sample design of a Non-NPIAS Airport. Standard dimensions are as shown in Table 1.

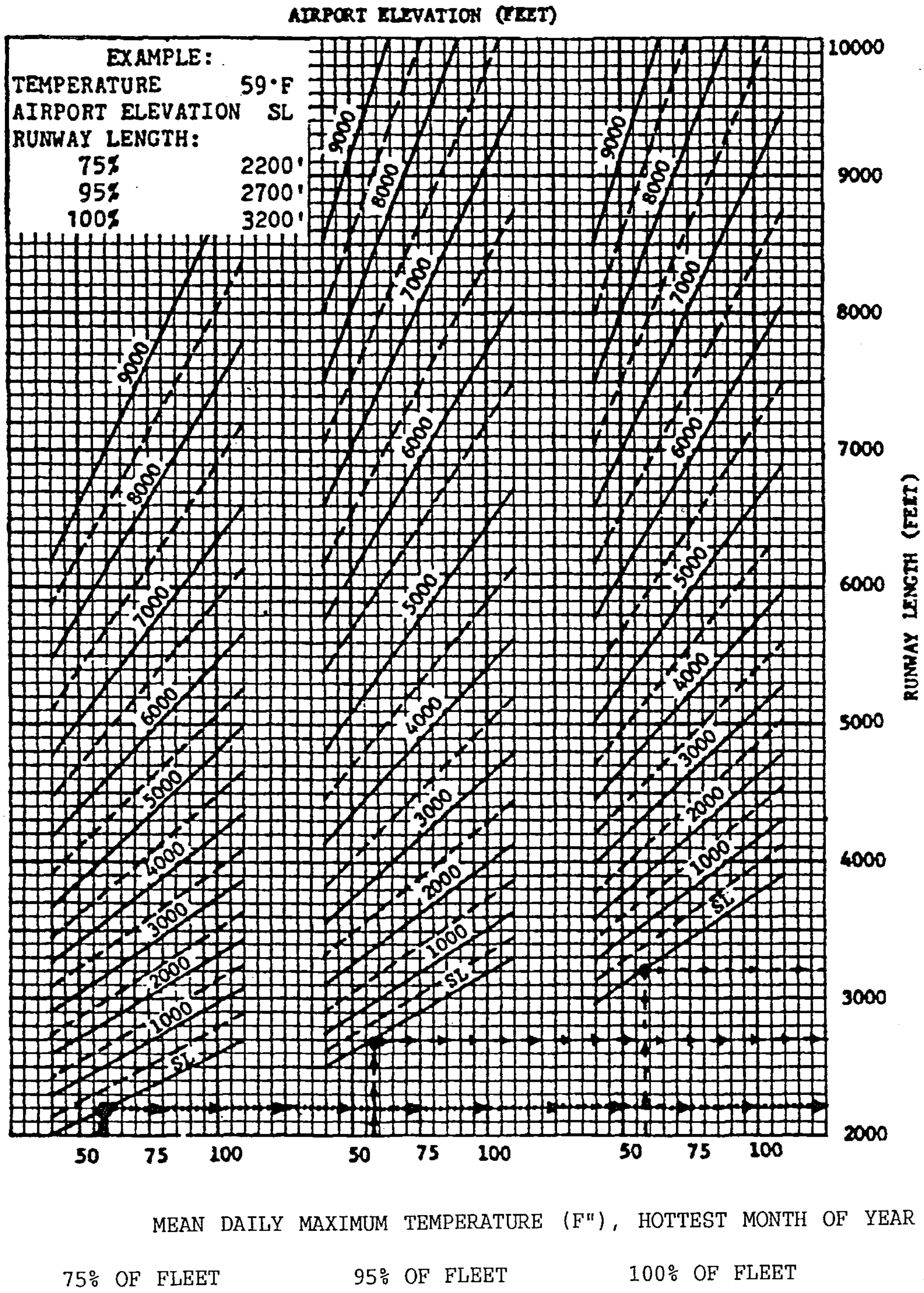
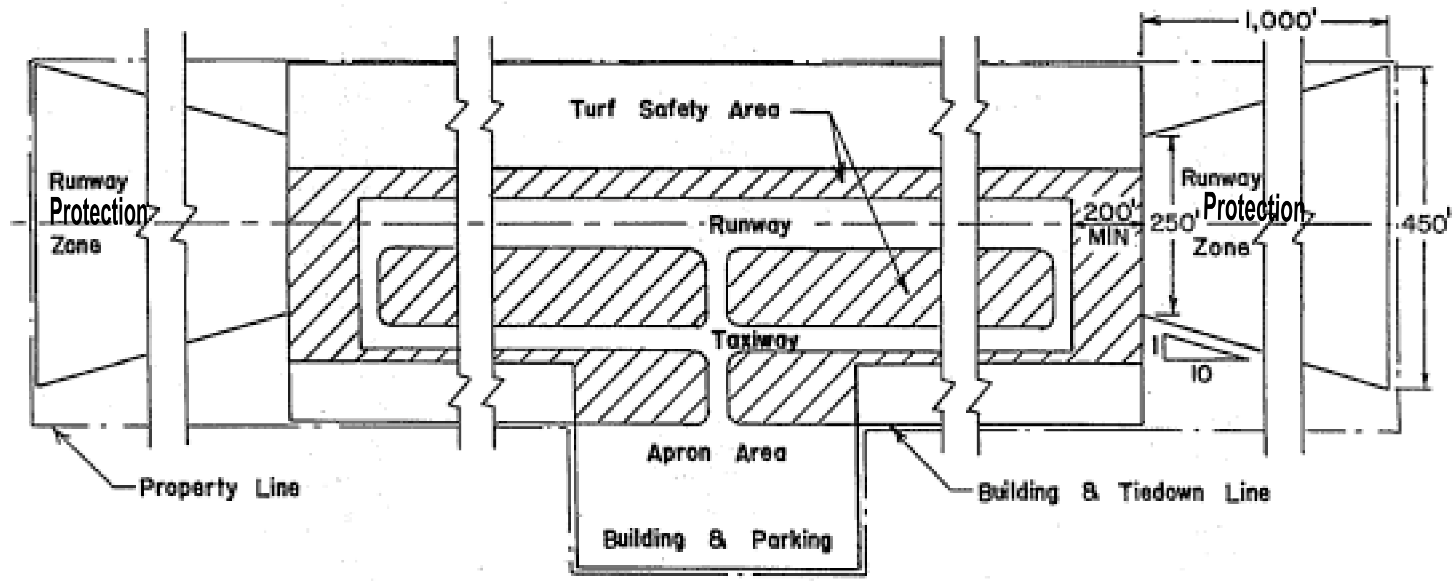


Figure 1
Runway Length to Serve Small Airplanes
Having Less Than 10 Passenger Seats



Sample Design
Community Airport

Figure 2

Table 1
Standard Dimensions

Design Standard	Minimum
RWY CL to Hold Line	125'
RWY CL to TWY CL	150'
RWY CL to A/C Parking	125'
RWY Width	60'
RWY Shoulder Width	10'
Obstacle Free Zone, OFZ	250'
RWSA Width	120'
RWSA Length Beyond RWY End	240'
RWOFA Width	250'
RWOFA Length Beyond RWY End	240'
Blast Pad Width	80'
Blast Pad Length	60'
TWY CL to Parallel TWY CL	69'
(TWY CL to Fixed or Moveable Object)	44.5'
TWY Width	25'
TSA Width	49'
TOFA Width	89'
TWY Shoulder Width	10'
Taxilane OFA Width	79'

Note: The dimensions shown in Table 1 above are based on a critical aircraft having a maximum take off weight of 12,500 pounds and an approach speed of 50 to 121 knots. These criteria coincide with guidance provided in FAA Advisory Circular 150/5300-13, Change 7. The WSDOT Aviation Division is currently considering adopting FAA design standards as the Washington State standard. Until a formal decision has been announced, all new airport development shall be planned and constructed using current FAA design standards.

2. Runway Protection Zone. Figure 2 shows the end of the runway, a 200-foot separation, and the runway protection zone. The runway protection zone is an area that must be kept free of all obstacles for the safe takeoff and landing of all airplanes. For visual approach only runways, it is defined as the space below a sloped plane beginning 200 feet from the end of the runway and rising at the rate of 1 foot for 20 feet horizontally. The runway protection zone also widens at the rate of 1 foot per 10 feet on each side.

In addition to the slopes noted, this runway protection zone must have minimum ground clearance over other transportation facilities. These minimum dimensions are shown in Figure 3. The area just beyond the runway protection zones must also be free of obstructions to flight. It is very important to consider these often forgotten areas during the planning phase.

3. Acreage Requirements. Table 2 shows approximate acreage requirements for airports with a configuration similar to that shown in Figure 2.

Table 2
Approximate Acreage Requirements

Runway Length (Feet)	Acres Required
2000	55
3000	67
4000	78
5000	86

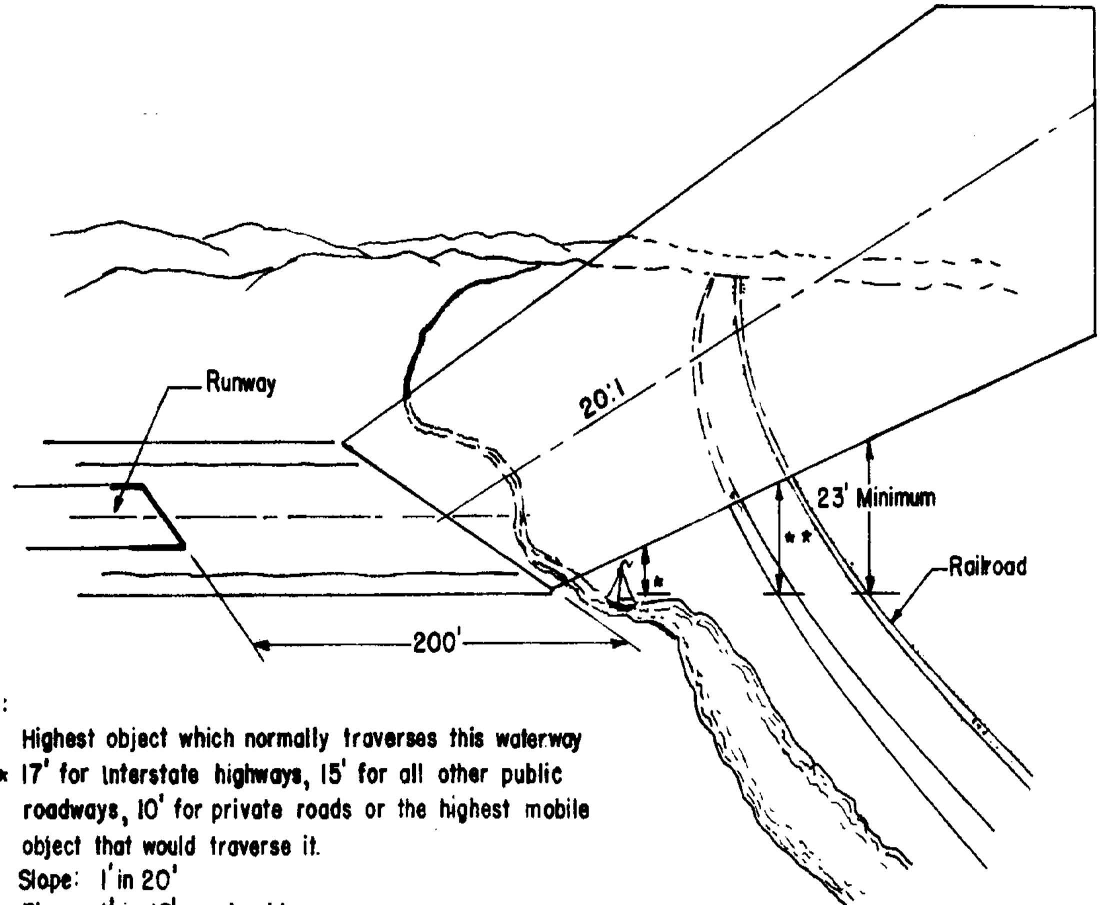
It is important to acquire control of the property within the runway protection zone (see Figure 2), plus that which may be required for obstacle removal and approach protection. The approach-departure areas are the most critical; control of these areas is essential and is preferably acquired by purchase of the land. If title cannot be obtained, avigation (navigation of aircraft) easements may be acquired, although this is less desirable. The acreage required for obstacle removal and approach protection varies with the location. Factors to consider include environment around the approach ends of the runway, local laws and ordinances, and zoning restrictions.

C. SITE EVALUATION

Factors to be evaluated in comparing various potential airport sites are listed below. A sample preliminary checklist of engineering information is included at the end of this section. Whenever an airspace review is required by Federal Aviation Regulation Part 157, the airport developer must obtain and process FAA Form 7480- 1, Notice of Landing Area Proposal.

1. Site Clearing. Estimate the extent and cost of clearing the site (i.e., removing trees, brush, stumps, structures, and other obstacles). Hazards must be removed from the approach area as well as from the runway area.

2. Soils Survey. A preliminary soils survey is conducted to determine soil suitability and depth and type of surfacing material that will be required on this soil. Take borings for testing to determine surfacing and paving depths for the runway, taxiway, and access road; borings should extend several feet below the proposed grade line to provide



Notes:

* Highest object which normally traverses this waterway

** 17' for Interstate highways, 15' for all other public roadways, 10' for private roads or the highest mobile object that would traverse it.

Slope: 1' in 20'

Flare: 1' in 10' each side.

Visual Approach
Runway Protection Zone

Figure 3

information on slope stability. Permeability tests are necessary wherever ground water could present a problem. In some cases, WSDOT may provide assistance in the preparation of the soils survey. Contact the WSDOT Aviation Division, Arlington, WA, for further details.

The soils survey should also include a determination of the availability and source of the surfacing and paving materials specified.

3. Drainage. Conduct a preliminary investigation to determine whether drainage structures will be necessary to supplement natural drainage courses; a contour map showing natural drainage of the site is helpful.

4. Airport Lighting. Determine the availability and estimated cost of the power source.

5. Utilities. Determine utilities requirements (i.e., water, sewer, communications, etc.), availability, and estimated cost. In those locations that are outside community water and sewage disposal systems, costs for onsite systems (well for water, and septic tank and drain fields for sewage disposal) must be included in the estimate. Review local ordinances that may affect your facility.

   It is important to review environmental considerations (see Section IV. Environmental Considerations Permits and Approvals) during the site evaluation process. It is the responsibility of the individual or local agency wishing to build the airport to ensure that all environmental processes are completed as required. Failure to comply with environmental impact requirements could result in delays or work stoppages.

PRELIMINARY ENGINEERING
CHECKLIST FOR FIELD INVESTIGATION

City_______________County _____________________________________ State______________

1. Location:

(a) Coordinates: Latitude_____________________Longitude________________

(b) Elevation_______________feet msl.

(c) Section, Township, Range____

(d) Distance to nearest communities_____________________________________

(e) Relation to other airports____

(f) Aeronautical Chart____

(g) U.S.G.S. Quadrangle Sheet____

2. Climatological Data:

(a) Annual rainfall_______inches Frost penetration__________inches
Snowfall__________inches

(b) Prevalence of_________Smoke_________Fog__________Flooding_____________

(c) Prevailing winds: Summer___________________Winter______________________

(d) Normal maximum temperature of hottest month_____degrees F

(e) Source of meteorological data____

____

(f) Unusual weather conditions____

____

3. Preliminary design data:

(a) Airport category____________________________________

(b) Recommended runway length_________feet

(c) Percent wind coverage______________________________

(d) Crosswind runway length____________________________

(e) Type & direction of instrument procedure________________

4. Site clearing:

(a) On-site acreage____________________

(b) Approach area acreage__________________________

(c) Other obstructions____
(trees, power lines, roads, etc.)

5. Soils survey:

(a) Number of borings___________________________________

(b) Estimated depth of water table________________________________

(c) Noteworthy features (stony, swampy, type cover, etc.)_____________

____

6. Drainage:

(a) Natural drainage courses_____________________________________

____

(b) Total tributary area acreage___________________________________

(c) Method of estimating runoff__________________________________

____

(d) Major drainage structures anticipated___________________________

7. Grading:

(a) Unclassified excavation (cut and fill)_____________________cu. yd.

(b) Borrow material _____________________________________cu. yd.

8. Preliminary pavement design:

   (a) Thickness of compacted subgrade______________________________

   (b) Thickness of subbase____

   (c) Thickness of base course_____________________________________

   (d) Thickness of wearing surface__________________________________

   (e) Distance to base material_____________________________________

   (f) Location of asphaltic concrete plant____________________________

   (g) Length and width of access road_______________________________

9. Turfing:

   (a) Specie chosen____

   (b) Total area to be turfed ____acres

10. Airfield lighting:

   (a) Type of lighting____
   ____

   (b) Other visual aids (such as VASI, REILS, etc.)__________________________________

   (c) Obstruction lighting____

11. Utilities:

   (a) Water supply source____

   (b) Sewerage--disposal system____

   (c) Telephone source____

   (d) Power--KVA available____

   (e) Gas--supply source____

12. Estimated cost for airport construction:

	Item	Unit	Cost	Quantity	Amount
a.	Clearing, on-site	Acre			
b.	Clearing, off -site	Acre			
c.	Obstruction removal	Lump Sum			
d.	Unclassified excavation	Cu. Yd.			
e.	Borrow	Cu. Yd.			
f.	Drainage				
	(a) Pipe	Lin. Ft.			
	(b) Structure	Lump Sum			
	(c) Other				
g.	Pavement				
	(a) Airport	Ton			
	(b) Road	Ton			
h.	Turfing	Acre			
i.	Lighting				
	(a) Runway, Taxiway, Apron, and Beacon	Lump Sum			
	(b) Visual Aids	Lump Sum			
	(c) Obstruction	Lump Sum			
j.	Utilities				
	(a) Water	Lump Sum			
	(b) Sewage	Lump Sum			
	(c) Other	Lump Sum			
k.	Miscellaneous				
	(a) Fencing	Lin. Ft.			
	(b) Runway Marking	Lump Sum			
	(c) Segmented Circle and Wind Cone (Lighted or unlighted)	Lump Sum			
				TOTAL	

13. Total estimated cost for:
Engineering, Supervision, Inspection and Administration, and Construction Contingencies — TOTAL ________

14. Total Estimated Cost for Airport Project
(excluding land acquisition) — TOTAL ________

COMMENTS:

____

____

____

____

____

____

____

____

____

____

Date of Investigation: _____________ Engineer: _________________

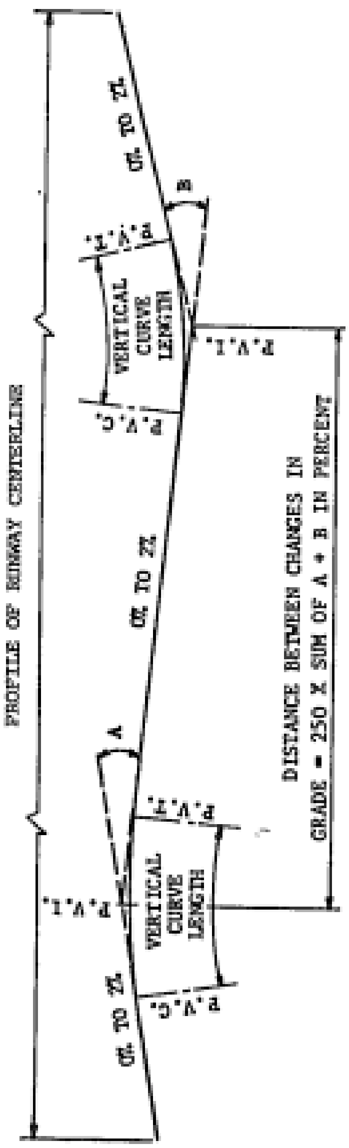
Appendix A
Surface Gradient Standards

Surface gradient standards include standards for runway and runway safety areas grades, taxiway and taxiway safety area grades, apron grades, and line of sight. These standards are discussed below:

Runway

The following longitudinal and transverse gradient standards for runways are also illustrated in Figures A-1 and A-2.

- The maximum longitudinal grade is ±2 percent. It is desirable to keep longitudinal grades to a minimum.
- The maximum allowable grade change is ±2 percent. Use longitudinal grade changes only when absolutely necessary.
- Vertical curves for longitudinal grade changes are parabolic. The length of the vertical curve is a minimum of 300 feet (90 m) for each 1 percent of change. No vertical curve is necessary when the grade change is less than 0.4 percent.
- The minimum allowable distance between the points of intersection of vertical curves is 250 feet (75 m) multiplied by the sum of the grade changes (in percent) associated with the two vertical curves.
- Figure A-2 presents maximum and minimum transverse grades for runways. In all cases, keep transverse grades to a minimum, consistent with local drainage requirements.



VERTICAL CURVES

LENGTH OF VERTICAL CURVES WILL NOT BE LESS THAN 300' FOR EACH 1% GRADE CHANGE, EXCEPT THAT NO VERTICAL CURVE WILL BE REQUIRED WHEN GRADE CHANGE IS LESS THAN 0.4%.

GRADE CHANGE

MAXIMUM GRADE CHANGE SUCH AS (A) OR (B) SHOULD NOT EXCEED 2%.

Figure A-1 – Longitudinal Runway Grade Limitations

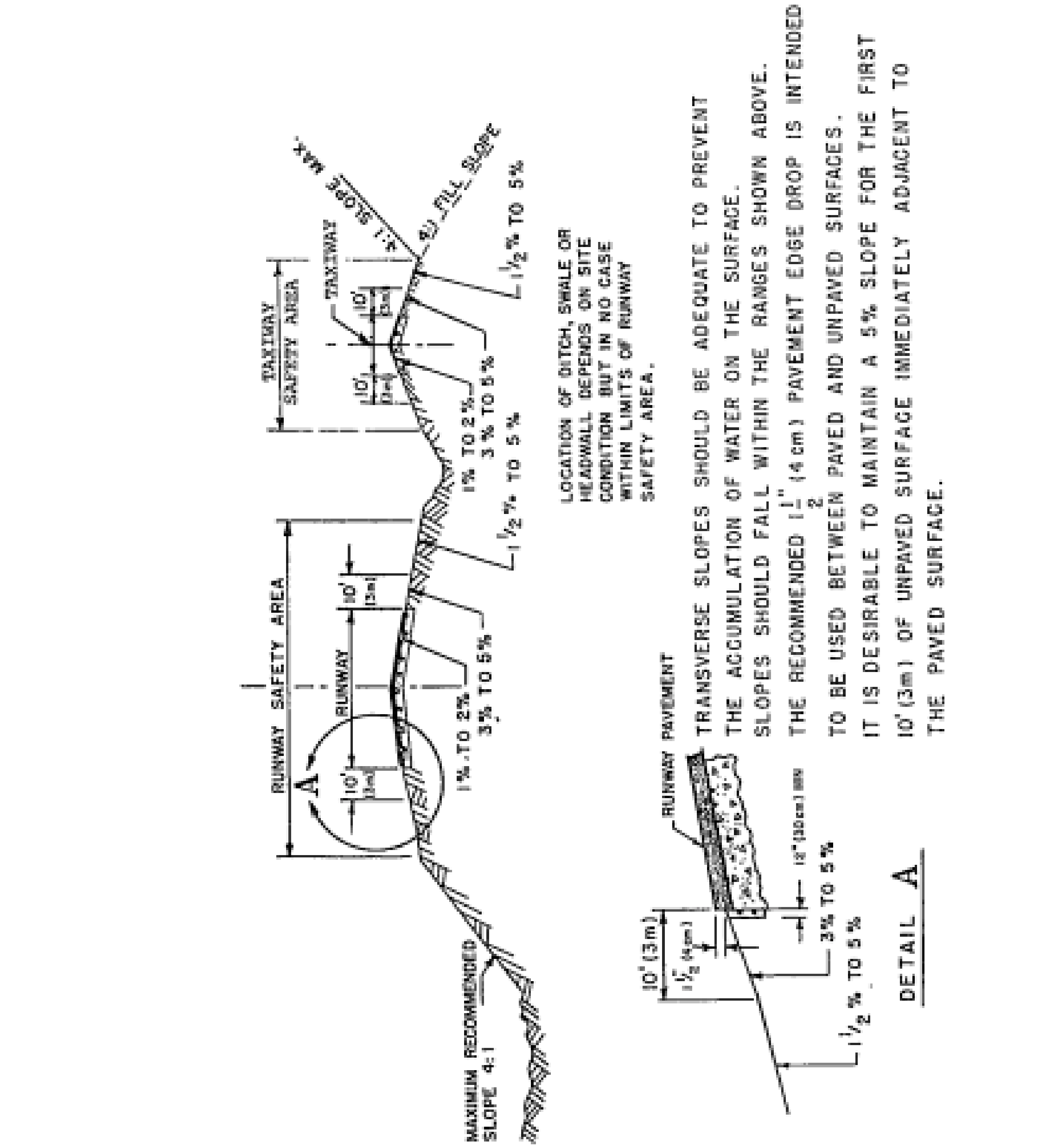


Figure A-2 – Transverse Runway and Taxiway Grade Limitations

Runway Safety Area Grades

- Longitudinal grades, longitudinal grade changes, vertical curves, and distance between changes in grades for that part of the runway safety area between the runway ends are the same as the comparable standards for the runway. Exceptions are allowed when necessary because of taxiways within the area. In such cases, modify the longitudinal grades of the runway safety area by the use of smooth curves. For the first 200 feet (60 m) of the runway safety area beyond the runway ends, the longitudinal grade is between 0 and 3 percent, with any slope being downward from the ends. For the remainder of the safety area, the maximum longitudinal grade is such that no part of the runway safety area penetrates the approach surface. The maximum allowable negative grade is 5 percent. Limitations on longitudinal grade changes are plus or minus 2 percent per 100 feet (30 m). Use parabolic vertical curves where practical.

Taxiway and Taxiway Safety Area Grades

- The longitudinal and transverse gradient standards for taxiways and taxiway safety areas are as follow:

  The maximum longitudinal grade is 2 percent. Minimum longitudinal grades are desirable.

  Avoid changes in longitudinal grades unless no other reasonable alternative is available. The maximum longitudinal grade change is 3 percent.

  When longitudinal grade changes are necessary, the vertical curves are parabolic. The minimum length of the vertical curve is 100 feet (30 m) for each 1 percent of change.

  The minimum distance between points of intersection of vertical curves is 100 feet (30 m) multiplied by the sum of the grade changes (in percent) associated with the two vertical curves.

  At any point on a taxiway centerline, the allowable difference in elevation between the taxiway and the corresponding point on the associated runway is 1.5 percent of the shortest distance between the points.

  Figure A-2 shows the maximum and minimum transverse grades for the taxiways and taxiway safety areas. In all cases, the transverse grades should be at a minimum, consistent with local drainage requirements.

Apron

To ease aircraft towing and taxiing, apron grades should be at a minimum, consistent with local drainage requirements. The maximum allowable grade in any direction is 2 percent. Where possible, design apron grades to direct drainage away from any building, especially in fueling areas.

Runway Line of Sight

An acceptable runway profile permits any two points five feet (1.5 m) above the runway centerline to be mutually visible for the entire runway length. However, if the runway has a full length parallel taxiway, the runway profile may be such that an unobstructed line of sight will exist from any point five feet (1.5 m) above the runway centerline to any other point five feet (1.5 m) above the runway centerline for one-half the runway length.

Taxiway Line of Sight

There are no line of sight requirements for taxiways. However, the sight distance along a runway from an intersecting taxiway needs to be sufficient to allow a taxiing aircraft to enter safely or cross the runway.

Appendix B
Stormwater Design Methodology

Introduction

Rainfall in Washington State is as varied as its topography. In a 2-year storm event, the City of Forks can receive as much as 5 inches of rain in a 24 hour period, while the City of Moses Lake receives as little as 8/10 of an inch in 24 hours. Regulations for the design of storm drainage retention/detention, erosion control, and water quality facilities therefore require consideration of these differences. To that end, the Washington State Department of Ecology has divided the state into two regions, west and east.

The *Stormwater Management Manual for Western Washington* was issued in September of 2001. The boundary of the Western Region is the Pacific Ocean on the west, the Canadian Border on the north, the Columbia River on the south and the Crest of the Cascade Mountain Range on the east.

The Eastern Region of Washington covers the remainder of the state, east of the crest of the Cascade Mountain Range. At the southern end of the Cascade Mountain Range, where the crest does not follow the county borders, the line then follows the western borders of Yakima and Klickitat Counties. *The Stormwater Management Manual for Easter Washington* is in DRAFT form and was issued in September of 2002.

It is important to note that these two manuals are not regulation. These manuals are only guidance documents, or tools, which local governments, state and federal agencies, developers, and project proponents can utilize for compliance with the State Water Pollution Control Act and the Federal Clean Water Act regulatory requirements for stormwater management. Federal, state, and local permitting authorities with jurisdiction can also require more stringent measures that are deemed necessary to meet locally established goals, state water quality standards, or other established natural resource or drainage objectives.

A map of Washington State showing the location of the Non-NPIAS airports within their respective region is attached. (See Figure B-1.)

Methodology For Conceptual Sizing Of Storm Drainage Facilities For Funding Application Purposes

As a guide for estimating the size of storm drainage facilities, see Figures B-2 through B-4 for the 2-, 10-, 25-, and 100-year, 24-hour Isopluvial maps of Washington State, with the precipitation in tenths of an inch. The Washington non-NPIAS airports have been overlaid on each map to assist in estimating the rainfall intensity at each airport.

Run-Off Volume. To approximate the runoff volume for each of the storm events, first determine the area of paved surface in acres. One acre is equivalent to 43,560 square feet of surface. Then locate the airport in question on the Isopluvial map for the storm for which the drainage facility will be sized (i.e., 2-, 10-, 25-, or 100-year storm). Interpolate between the rainfall lines to determine what the total rainfall amount will be. Divide the number of tenths of an inch by 12 to convert to feet. Now, multiply the number of acres of paving by the feet of rain that will fall in 24 hours. The resulting answer will be the approximate number of acre-feet of rain the pavement surface will produce for that given storm. If the surface area is small, there is no need to convert square feet of paved surface to acres. The result will be the approximate number of cubic feet of stormwater to be handled in the stormwater facility.

Pipe Sizing. Use the section titled "Calculating Headwater for Inlet Control" and the Nomographs (Figures B-5 and B-6) from the Washington State Department of Transportation *Hydraulics Manual* (M23-03), January 1997 and the *Highway Runoff Manual* (31-16), February 1995 to size the stormwater collection and distribution system.

In Western Washington, tributary lines are normally sized to accommodate the 10-year storm event, and trunk lines sized to accommodate the 25-year storm event. In Eastern Washington, the tributary laterals are sized for the 2-year, 72-hour storm event, and the trunk main for the 25-year, 72-hour storm event.

Approximate Storage Facility Design. Even though we are able to estimate runoff volumes, it is still difficult to determine storage facility design requirements for the following reasons:

The presence of a stormwater outfall can have a significant affect on the size of the stormwater storage facility.

Size of an infiltration facility is, to a large degree, determined by infiltration rate and infiltration rates can vary considerably at different airport locations.

In order to get a better estimate of stormwater storage facility size requirements, it is recommended that a preliminary stormwater design be prepared by an engineer. If that is not practical, an average order of magnitude stormwater facility cost of $200,000 for a Western Washington airport and $100,000 for an Eastern Washington airport could be used for grant application and cost estimating purposes.

Water Quality. Stormwater quality is not expected to be difficult to achieve at the average non-NPIAS airport without terminal and FBO facilities. Most non-NPIAS airports will have an expanse of grass at the edge of the runway that will serve as a bio-swale for treating stormwater. Terminal and FBO facilities will require additional water treatment considerations.

Contract Document Design Sizing Of Stormwater Conveyance And Retention-Detention Facilities

As state earlier, the Department of Ecology (DOE) has chosen to divide the state into two regions, west and east. Sizing stormwater retention/detention facilities in Western Washington should be done using the *Stormwater Management Manual for Western Washington* along with local ordinances and regulations. Sizing stormwater retention/detention facilities in Eastern Washington should be done using *the Draft Stormwater Management Manual for Eastern Washington* along with local ordinances and regulations. The storm events are all unique, but for design purposes, the Soils Conservation Service (SCS) has identified the storm types in Western Washington as Type 1A and in Eastern Washington as Type II. A professional engineer, licensed in Washington State, and both knowledgeable and qualified to design these facilities is required to develop the plans and specifications for contract documents and to obtain the necessary permits and reports for these facilities.

Calculating Headwater for Inlet Control

When a culvert is flowing in inlet control, two basic conditions exist. If the inlet is submerged, the inlet will operate as an orifice. If the inlet is unsubmerged, the inlet will operate as a weir. Equations have been developed for each condition and the equations demonstrate the relationship between headwater and discharge for various culvert materials, shapes, and inlet configurations. The inlet control nomographs shown, Figures B-5 and B-6, utilize those equations and can be used to solve for headwater.

(*Note:* The designer should check to ensure that the appropriate nomograph is chosen, based on the culvert material and shape used for design.)

Instructions on determining headwater, culvert size, and discharge can be obtained from WSDOT – Aviation Division on request.

Figure B-1, the Eastern and Western Washington Drainage Basins for Non-NPIAS Airports Map can be obtained from WSDOT – Aviation Division on request.

Figure B-2, the 10-Year, 24-Hour Precipitation Isopluvials, Non-NPIAS Aviation System Plan Map can be obtained from WSDOT – Aviation Division on request.

Figure B-3, the 25-Year, 24-Hour Precipitation Isopluvials, Non-NPIAS Aviation System Plan Map can be obtained from WSDOT – Aviation Division on request.

Figure B-4, the 100-Year, 24-Hour Precipitation Isopluvials Non-NPIAS Aviation System Plan Map can be obtained from WSDOT – Aviation Division on request.

Figure B-5, Concrete Pipe Inlet Control Nomograph can be obtained from WSDOT – Aviation Division on request.

Figure B-6**,** Corrugated Metal and Thermoplastic Pipe Inlet Control Nomograph can be obtained from WSDOT **–** Aviation Division on request.

Appendix C
Pavement Design Methodology for Non-NPIAS Airports
12,500 lb. and Under

General

Pavement can be designed using the FAA or AASHTO methodology. FAA design can be done using the design curves in FAA Advisory Circular 150/5320-6D or the FAA pavement design computer program, Flexible Pavement Design.

Pavements designed using the FAA methodology and WSDOT materials will require the following thickness adjustments:

Thickness Adjustment for WSDOT Materials

Aircraft Gross Weight Category	Recommended Equivalent Pavement Section When Using State Highway Materials and Specifications
12,500 lb. and under	AC = FAA design thickness plus ¼ - inch 50-blow Marshall equivalent Base =FAA design thickness plus 1 inch Subbase =Thickness required to meet FAA design total thickness.

The use of the FAA design methodology and WSDOT materials is recommended for the following reasons:

Aircraft design weights can be used directly without converting from highway axle loads to aircraft loads.

The FAA methodology is less complex and easier to use. There are several inputs into the AASHTO methodology that are not easily obtained for airport design.

Pavement Design for Grant Application

Table C-1 considers pavement sections for three different soils conditions, poor, average and good. Poor soils would have a California Bearing Ratio (CBR) of 3 and would be characterized as fine graded, clay and organic soils, poorly drained and very susceptible to moisture. Average soils would have a CBR of 7, would consist of sandy silt and would be somewhat poorly drained. Good soils would have a CBR of 13, would be fairly well drained and would consist of silty, gravelly sand. Table C-1 can be used to approximate a pavement design section for preliminary cost estimating and grant application purposes:

Table C-1

Estimating Pavement Section Thickness for Grant Application Purposes

Design Weight	Soil Bearing Capability (CBR)	Pavement Section	
12,500 lb. (SWG)	3	WSDOT Class B Asphalt	2-1/4"
		WSDOT Crushed Surfacing Base Course	14"
12,500 lb. (SWG)	7	WSDOT Class B Asphalt	2-1/4"
		WSDOT Crushed Surfacing Base Course	9"
12,500 lb. (SWG)	13	WSDOT Class B Asphalt	2-1/4"
		WSDOT Crushed Surfacing Base Course	6"

Contract Document Pavement Design

Design of airfield pavement is a complex process that includes design considerations that vary widely and interact with and affect each other. Pavement sections for contract and construction purposes therefore need to be designed by a professional engineer with experience in airfield pavement design.

There may be loads on the pavement that are more demanding than the 12,500 lb. aircraft loads, such as snow plows and emergency vehicles. If this is the case, the pavement must be designed for these heavier loads.

It is also important to take seasonal frost effects into account in the pavement design. The designer should refer to FAA, Advisory Circular No. 150/5320-6D for seasonal frost considerations.

Appendix D
Airfield Lighting

General

Design associated with development of airport edge lighting can be either a parallel or series system. The number of edge lights supplied by a parallel system is limited due to the increased current and the subsequent voltage drop. Voltage drop of a parallel system is a function of current change due to number of lights and increased wire length. Voltage drop of a series system is a function of increased wire length only because current is constant and at a low magnitude throughout the system.

Field installation of a parallel system is less complex than that of a series system in that the system is comprised of a power source, wire and load devices. A series system requires added interfacing isolation transformers due to the voltage configuration at the secondary of a series system control regulator. A parallel system requires three wires per run to include two ungrounded legs and a grounded neutral throughout the length of a system. A series system requires only a single wire loop around the edge of the runway or taxiway system.

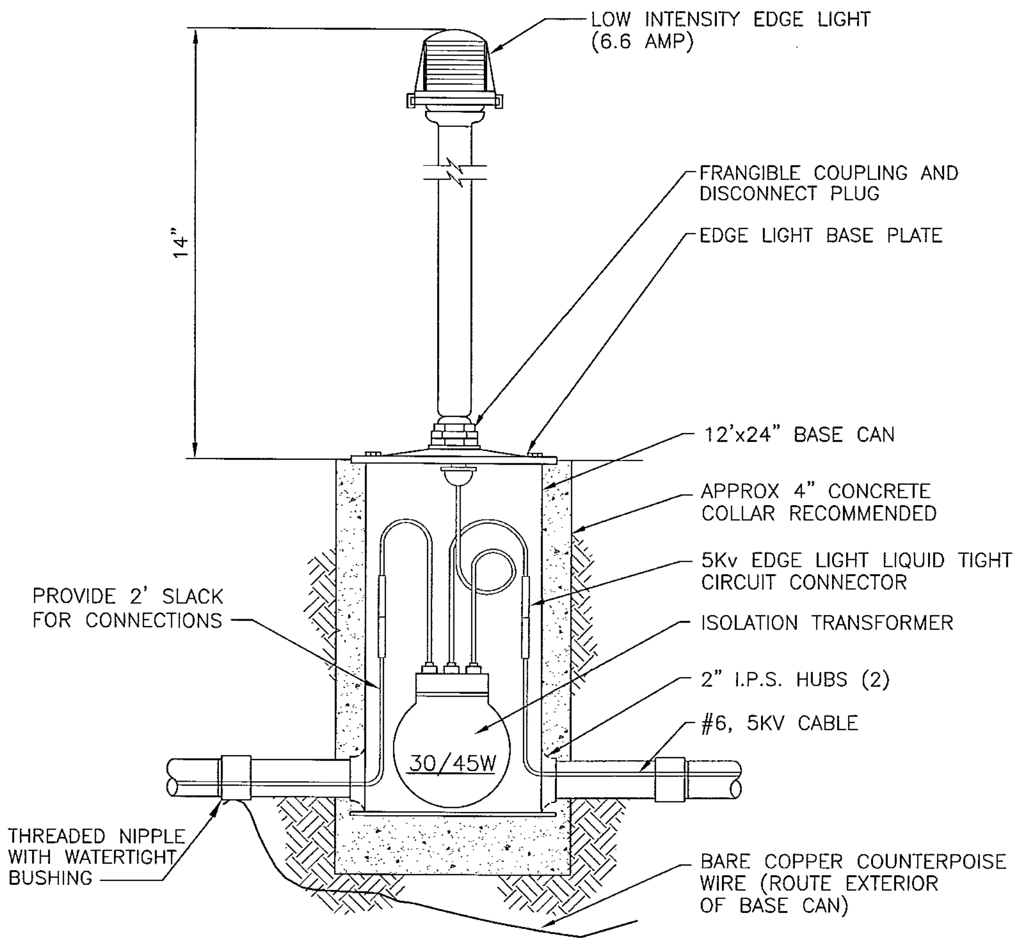
Parallel Wired Edge Lighting System

A parallel edge lighting system is comprised of a power supply panelboard with appropriately rated branch circuit overcurrent protective device, a three wire per circuit distribution system, non-metallic raceway for direct earth burial, 120 volt base can or stake mounted edge lights, base can or stake mounts, handholes as applicable and wire connecting devices. The parallel system shall include a counterpoise (grounding) wire to protect the edge lighting system from lightning strike and also to minimize probability of injury due to electrical shock. Due to voltage drop, placement of a parallel supply circuit around the entire perimeter of the edge lighting system is impractical. Circuits are required to be minimal length and require that the length be computed to maintain a minimal voltage differential between edge lights for constant light intensity. Voltage drop differential within a circuit shall not exceed three percent from the source to the outermost light. Light brightness differential can be noticeable if the voltage drop is more than three percent. Each parallel system is required to be supplied by a three-wire system simply to minimize the level of neutral current. A load balance between ungrounded wires results in little or no neutral current. Neutral current imposes additional voltage drop from added wire length. Wire for a parallel edge lighting system is required to be suitable for direct earth burial even though the cable will be installed in an approved raceway. Radio control of a parallel system is single step and is applied through an interfacing lighting contactor.

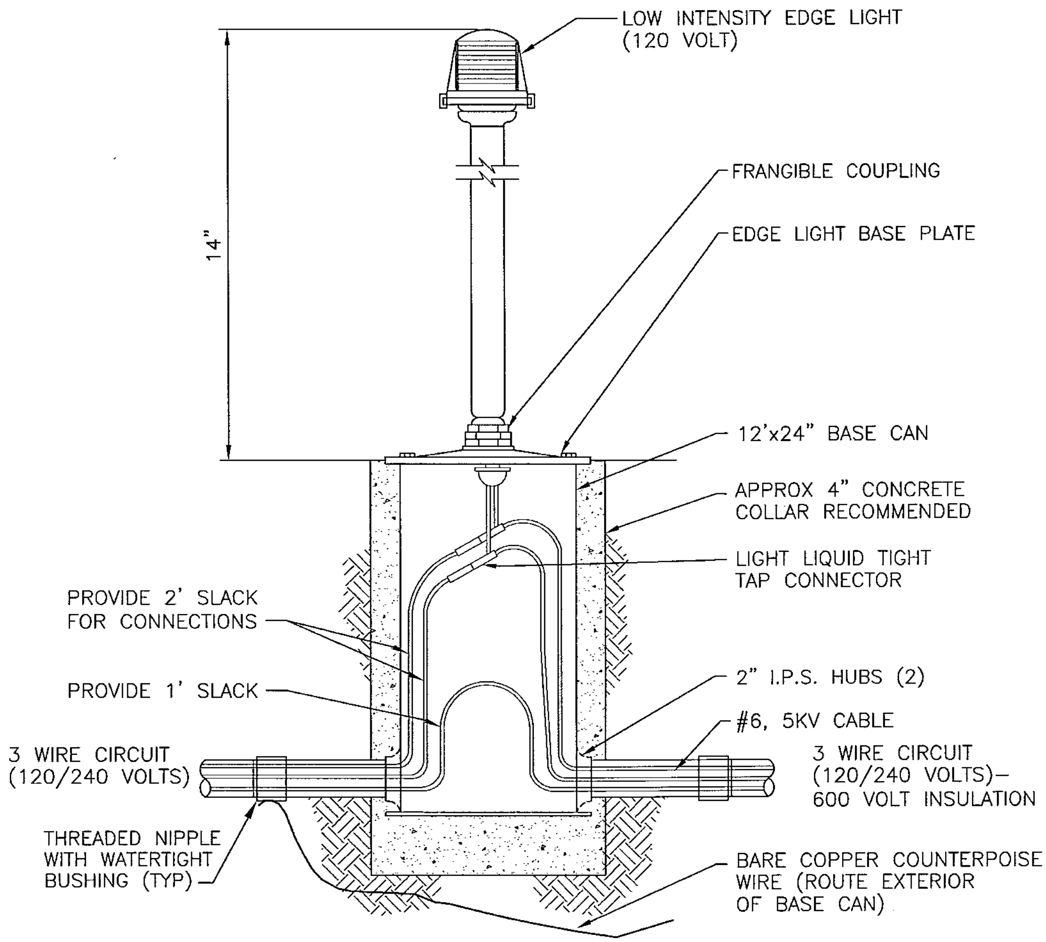
Series Wired Edge Light System

Although more physically complex than a parallel system, a series edge lighting system is more ideal in that the number of edge lights and the length of runway has no effect on the brightness of connected lights. A series system is comprised of a power supply regulator, an enclosure to house the regulator, a branch circuit to supply the regulator, medium voltage wire, non-metallic raceway for direct earth burial, isolation transformers at each edge light, base can or stake mounts, connectors for primary and secondary connection and 6.6 ampere maximum edge lights which may be either base can or stake mounted. The series system shall include a counterpoise (grounding) wire.

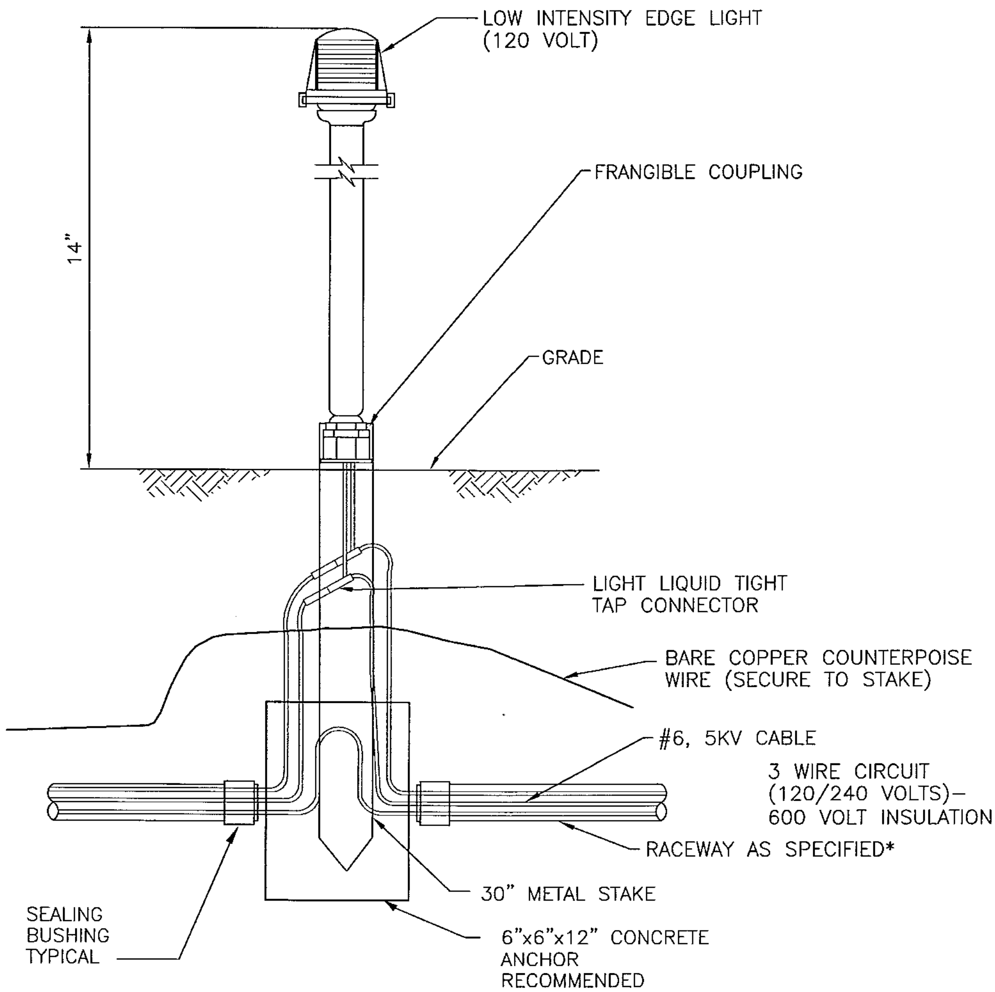
Edge lighting current supplied by a series circuit regulator is maintained at a constant magnitude, hence, all edge lights connected to the circuit are constant in brightness regardless of number of edge lights and length of runway. Another advantage of the series system is that lighting intensity can be varied. Each power supply regulator can be furnished with intensity control terminals, which are directly connected to a radio frequency lighting intensity controller. This is accomplished by three dry contact output relays, which control the regulator for three intensity outputs of 4.8, 5.5 and 6.6 amperes. These amperages translate to edge light brightness levels of 10, 70 and 100 percent of maximum lamp brightness.



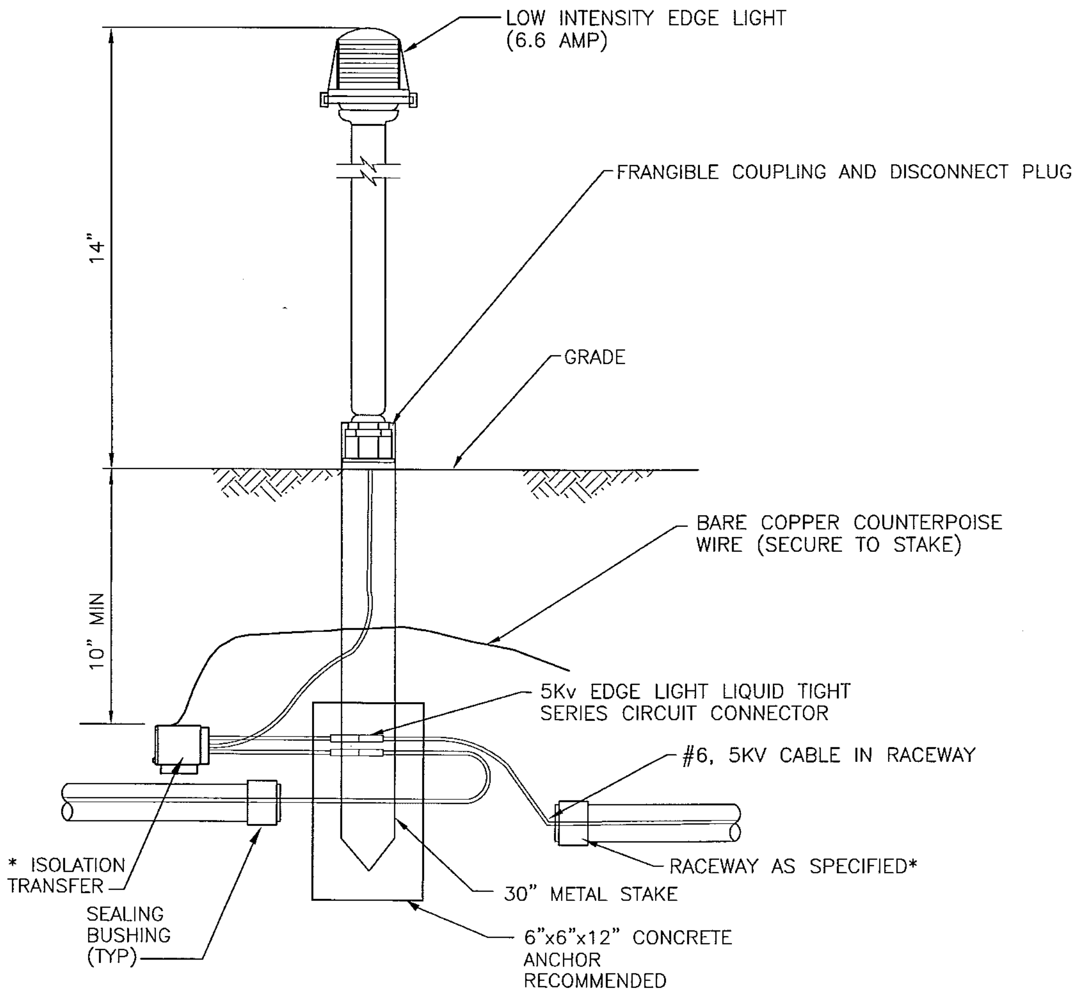
BASE MOUNTED SERIES CIRCUIT



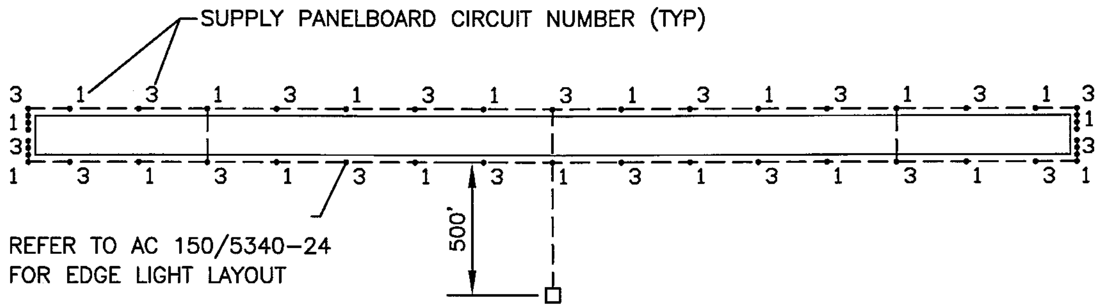
BASE MOUNTED PARALLEL CIRCUIT



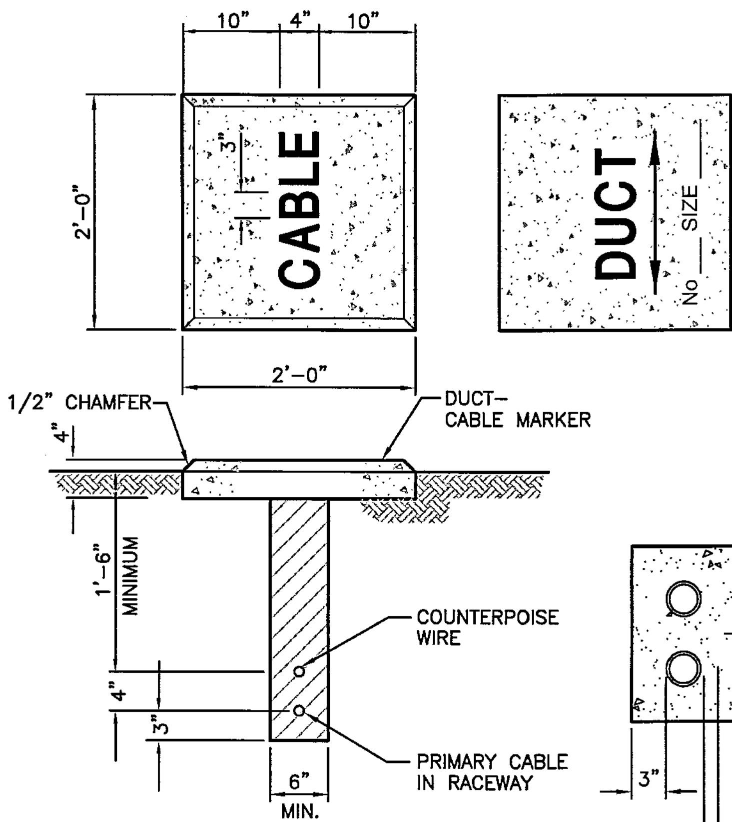
STAKE MOUNTED PARALLEL CIRCUIT



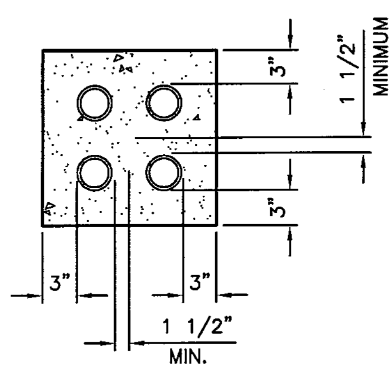
STAKE MOUNTED SERIES CIRCUIT



PLAN VIEW OF PARALLEL LIGHTING CONFIGURATION

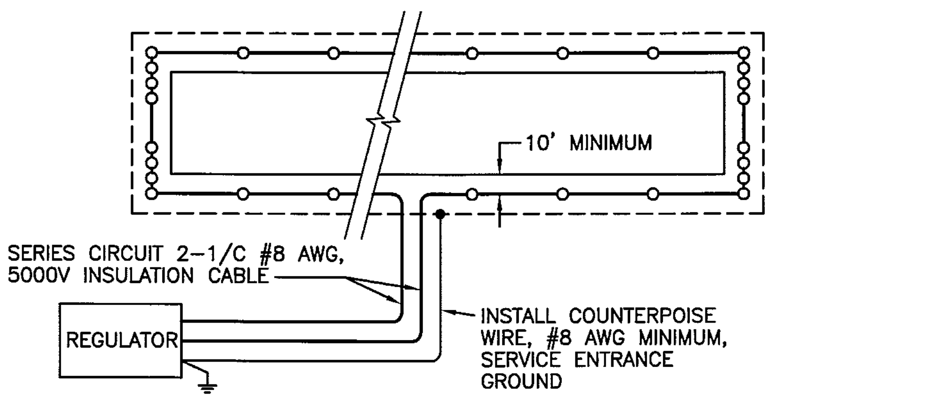


TYPICAL CABLE/DUCT MARKER DETAIL

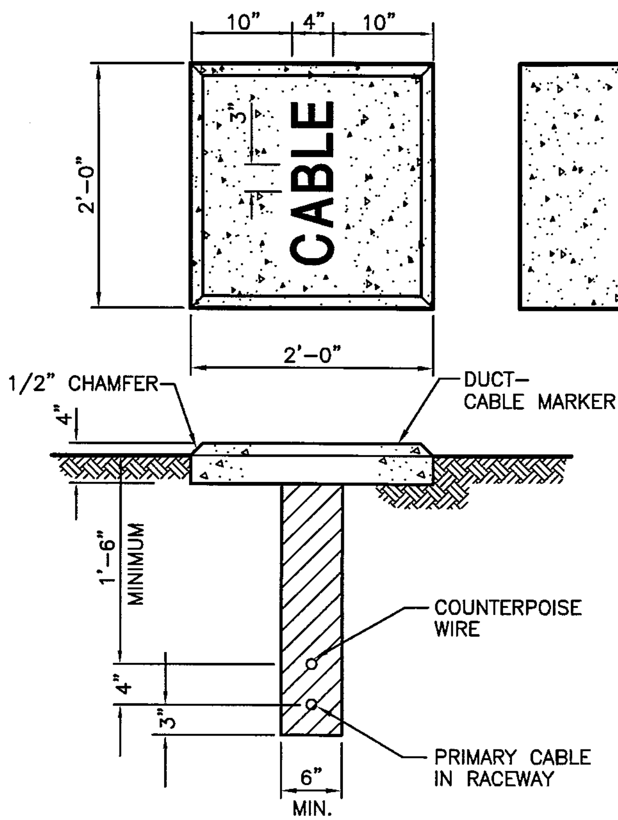


TYPICAL 4-WAY DUCT
(REFERENCE ONLY)

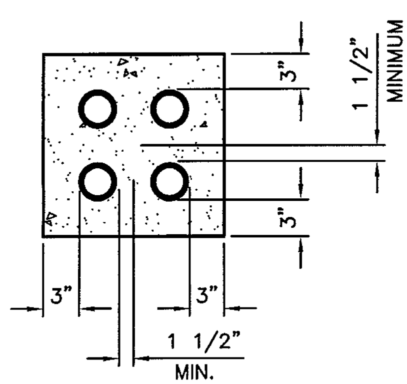
TYPICAL PARALLEL LIGHTING CONFIGURATION



PLAN VIEW OF SERIES LIGHTING CONFIGURATION



TYPICAL CABLE/DUCT MARKER DETAIL



TYPICAL 4-WAY DUCT
(REFERENCE ONLY)

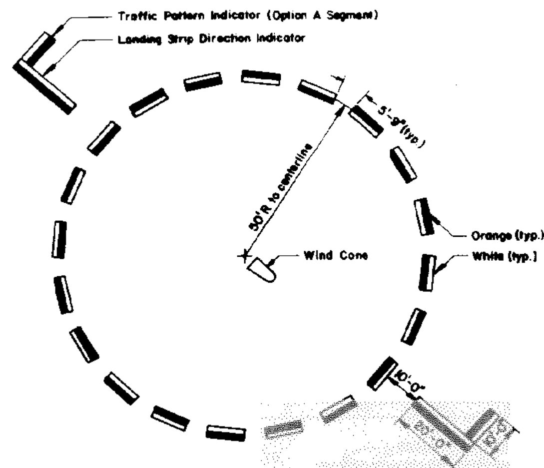
TYPICAL SERIES LIGHTING CONFIGURATION

Appendix E
Cost Estimate

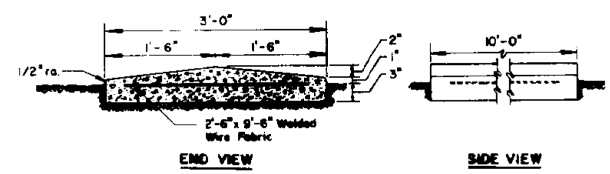
Table E-1

SUMMARY OF QUANTITIES			
ITEM	UNIT	QUANTITY	ESTIMATE
Clearing and Grubbing	Lump Sum		$5,000
Unsuitable Excavation (including haul)	Cubic Yard	950	$4,500
Asphalt Concrete	Ton	10,000	$350,000
Threshold Lights	Each	12	$2,500
Fencing	L.F.	14,700	$75,000
Paint Striping	L.F.	8,200	$1,5000

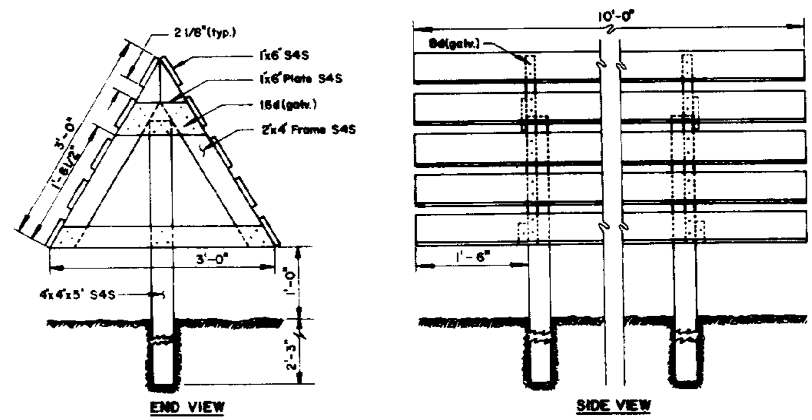
Note: This summary is only a partial listing for SAMPLE purposes ONLY.



PLAN



OPTION B



OPTION A

NOTES

Welded Wire Fabric shall conform to Standard Specification 9-18.2(7).

Placement of the Traffic Pattern Indicator and Landing Strip Direction Indicator shall be determined by the predominant wind direction.

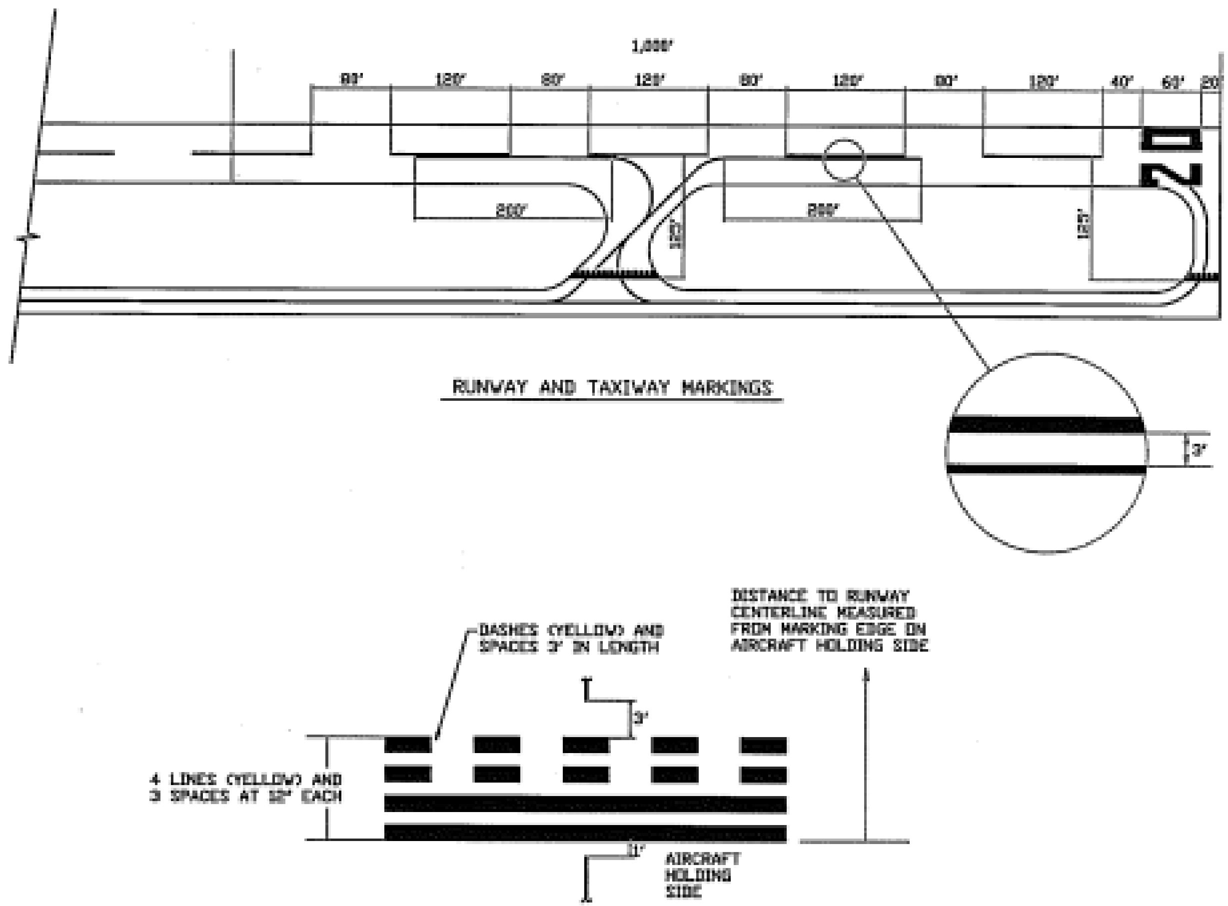
One (1) segment of Option A shall be placed in pipe sleeve supports for easy removal so as to access center area.

The Landing Strip Direction Indicator shall be one (1) 20 foot section with four (4) posts. The end post placement of 1'-6" shall be retained with the two (2) center posts equally spaced between.

Class C Concrete to be used for Option B.

SEGMENTED CIRCLE MARKER

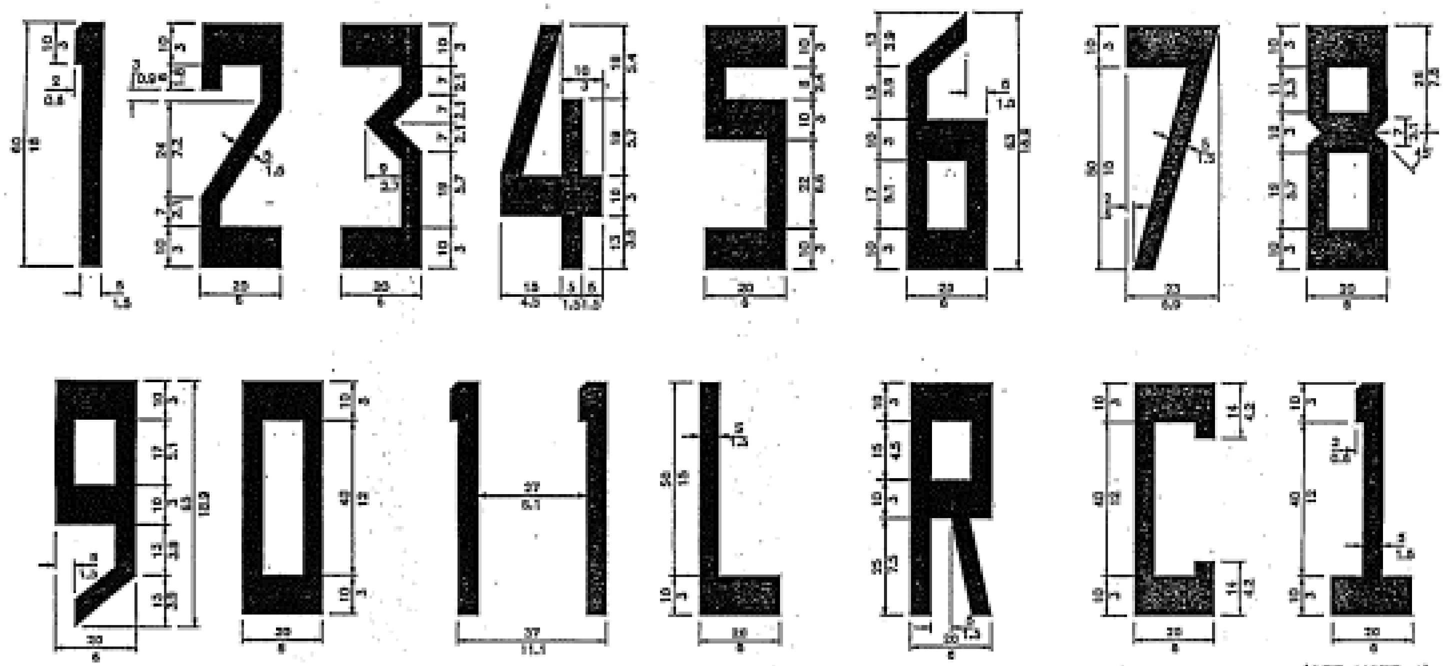
FIGURE E-1



RUNWAY AND TAXIWAY MARKINGS

RUNWAY HOLDING POSITION MARKINGS

FIGURE E-2



NOTES:

1. ALL NUMERALS EXCEPT THE NUMBER ELEVEN AS SHOWN ARE HORIZONTALLY SPACED 15 FEET (4.5 METERS) APART.
2. SINGLE DIGITS SHALL NOT BE PRECEDED BY A ZERO.
3. DIMENSIONS ARE EXPRESSED THUS: $\frac{\text{FEET}}{\text{METERS}}$ e.g. $\frac{30}{9}$
4. THE NUMERAL 1, WHEN USED ALONE, CONTAINS A HORIZONTAL BAR TO DIFFERENTIATE IT FROM THE RUNWAY CENTERLINE MARKING.
5. SINGLE DESIGNATIONS ARE CENTERED ON THE RUNWAY PAVEMENT CENTERLINE. FOR DOUBLE DESIGNATIONS, THE CENTER OF THE OUTER EDGES OF THE TWO NUMERALS IS CENTERED ON THE RUNWAY PAVEMENT CENTERLINE.
6. WHERE THE RUNWAY DESIGNATION CONSISTS OF A NUMBER AND A LETTER, THE NUMBER AND LETTER ARE LOCATED ON THE RUNWAY CENTERLINE IN A STACKED ARRANGEMENT AS SHOWN IN FIGURE 1.

FIGURE E-3

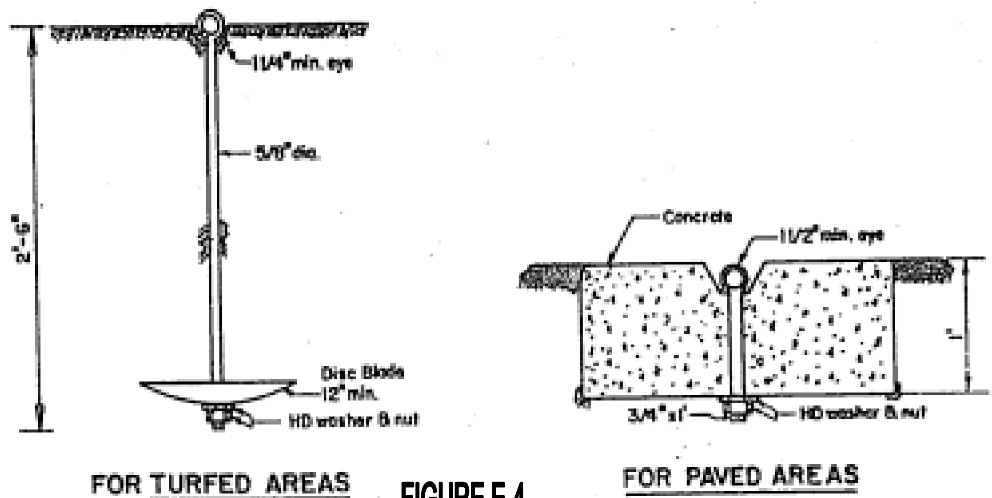


FIGURE E-4

TIE-DOWN ANCHORS